OFFICIAL NASA ROADMAPS











SOLID ROCKET PROPULSION

- Propellants Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion
- Fundamental Solid Propulsion Technologies LIQUID ROCKET PROPUL-

SION SYSTEMS LH₂/LOX Based

- RP/LOX Based CH4/LOX Based
- Detonation Wave Engines
- (Closed Cycle) Propellants
- Fundamental Liquid Propulsion Technologies AIR BREATHING

PROPULSION SYSTEMS

- TBCC RBCC
- **Detonation Wave Engines**
- (Open Cycle) Turbine Based Jet Engines (Flyback Boosters)
- Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles Air Collection &
- Enrichment System Fundamental Air Breathing
- Propulsion Technologies ANCILLARY PROPULSION

Systems Auxiliary Control Systems

- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems Thrust Vector Control
- Health Management &
- Pyro & Separation Systems Fundamental Ancillary Propulsion Technologies

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS Ground Launch Assist

- Air Launch / Drop Systems
- Space Tether Assis Beamed Energy / Energy
- High Energy Density

MASTER-12/20/12

TA04 · ROBOTICS, ROBOTICS&AUTONOMOUS SYSTEMS

- Terrain Mapping, Classification
- Natural & Man-made
- Sensor Fusion for Sampling & Manipulation Onboard Science Data Analysis

MOBILITY

- CHEMICAL PROPULSION • Liquid Storable
 - Small Body/Microgravity Mobility

- Modeling of Contact Dynamics Mobile Manipulation
- Collaborative Manipulation Robotic Drilling & Sample

Processing

- Systems Interaction

- Interfaces
- Human Proximity Operations

TA03 · SPACE POWER & **ENERGY STORAGE**

Power Generation Energy Harvesting

Liquid Cryogenic

• Micro-propulsion

• Electric Propulsion

Solar Sail Propulsion

• Thermal Propulsion

Tether Propulsion

ADVANCED (TRL <3)

PROPULSION TECHNOLOGIES

Electric Sail Propulsion

High Energy Density

Breakthrough Propulsion

Propellant Storage &

Fusion Propulsion

• Antimatter Propulsion

SUPPORTING TECHNOLOGIES

Advanced Fission

Beamed Energy Propulsion

Cold Gas/Warm Gas

NON-CHEMICAL PROPULSION

• Gels

Hybrid

- Chemical (Fuel Cells, Heat
- Engines) Solar (Photo-Voltaic & Thermal)
- Radioisotope Fission
- Fusion

ENERGY STORAGE Batteries

 Flywheels • Régenerative Fuel Cells

Power Management & DISTRIBUTION

- FDIR
- Management & Control Distribution & Transr
- Wireless Power Transmission
- Conversion & Regulation

CROSS CUTTING TECHNOLOGY

- Analytical Tools • Green Energy Impact
- Multi-functional Structures • Alternative Fuels

SENSING & PERCEPTION

- 3-D Perception Relative Position & Velocity Estimation
- & Characterization
- Object Recognition

- Extreme Terrain Mobility Below-Surface Mobility
- Above-Surface Mobility

MANIPUL ATION

- Robot Arms Dexterous Manipulators

HUMAN-SYSTEMS INTEGRATION

- Multi-Modal Human-Supervisory Control
- Robot-to-Suit Interfaces Intent Recognition &
- Distributed Collaboration Common Human-Systems
- Safety, Trust, & Interfacing of Robotic/

AUTONOMY • Vehicle Systems

- Management & FDIR
- Dynamic Planning & Sequencing Tools Autonomous Guidance & Control
- Multi-Agent Coordination Adjustable Autonomy
- Terrain Relative Navigation • Path & Motion Planning with Uncertainty

AUTONOMOUS RENDEZVOUS & Docking

• Relative Navigation Sensors (long-, mid-, near-range) Guidance Algorithms

for Autonomy/Automation

Verification & Validation of

Complex Adaptive Systems

Docking & Čapture Mechanisms/Interfaces • Mission/System Managers

RTA Systems Engineering

Onboard Computing

Modularity/Commonality

Human Factors ENVIRONMENTAL MONITORING. SAFETY & EMERGENCY RESPONSE

Behavioral Health

• Long-Duration Health

• Sensors: Air, Water, Microbial, etc. Fire: Detection, Suppression, Recovery Protective Clothing / Breathing

Remediation

- Risk Assessment Modeling Radiation Mitigation
- Protection Systems Radiation prediction Monitoring Technology

TA05 · COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

Detector Development

• Acquisition & Tracking

Atmospheric Mitigation

RADIO FREQUENCY COMMUNICATIONS

• Spectrum Efficient Technologies

Power Efficient Technologies

Earth Launch & Reentry Comm.

• Disruptive Tolerant Networking

• Integrated Network Management

• Timekeeping & Time Distribution

• Sensors & Vision Processing Systems

Science from the Comm. System

Neutrino-Based Nav. & Tracking

Quantum Key Distribution

Quantum Communications

• Reconfigurable Large Apertures

HABITATION SYSTEMS

ENVIRONMENTAL CONTROL

HARITATION SYSTEMS

Habitation

• Air Revitalization

Pressure Garment

& LIFE SUPPORT SYSTEMS &

Waste Management

Using Nanosat Constellations

TA06 · HUMAN HEALTH,

Water Recovery & Management

EXTRAVEHICULAR ACTIVITY SYSTEMS

• Portable Life Support System

Power, Avionics & Software

HUMAN HEALTH & PERFORMANCE

Medical Diagnosis / Prognosis

SOIF Microwave Amplifier

RF/Optical Hybrid Technology

Relative & Proximity Navigation

Auto Precision Formation Flying

Auto Approach & Landing

INTEGRATED TECHNOLOGIES

Cognitive Networks

Navigation Sensors

REVOLUTIONARY CONCEPTS

X-Ray Communications

X-Ray Navigation

Hybrid Optical Comm. &

Ultra Wideband

Position, Navigation, and Timing

Onboard Auto Navigation &

Adaptive Network Topology

Information Assurance

Flight & Ground Systems

Large Apertures

Propagation

Antennas

INTERNETWORKING

Maneuver

• Radio Systems







TA07 · HUMAN EXPLORATION **DESTINATION SYSTEMS**

- IN-SITU RESOURCE UTILIZATION
- Destination Reconnaissance
- Consumables Production Manufacturing Products

SUSTAINABILITY & **SUPPORTABILITY**

- Management Maintenance Systems
- Repair Systems

"ADVANCED" HUMAN MOBILITY SYSTEMS

- EVA Mobility Surface Mobility
- "ADVANCED" HABITAT SYSTEMS
- Habitat Evolution "Smart" Habitats

MISSION OPERATIONS & SAFETY

- Planetary Safety Integrated Flight Operations
- CROSS-CUTTING SYSTEMS
- Construction & Assembly Particulate Contamination Prevention & Mitigation

OBSERVATORIES & SENSOR SYSTEMS

REMOTE SENSING INSTRUMENTS/SENSORS

- Detectors & Focal Planes Electronics Optical Components
- Cryogenic / Thermal
- **O**BSERVATORIES Mirror Systems

In-SITU INSTRUMENTS/SENSOR

In-Situ

TA09 · ENTRY, DESCENT &

LANDING

- Prospecting, & Mapping Resource Acquisition
- & Infrastructure Emplacement

• Autonomous Logistics

Food Production, Processing, & Preservation

- Off-Surface Mobility
- Integrated Habitat Systems

Artificial Gravity

- Crew Training
- Integrated Risk Assessment Tools

TA08 · SCIENCE INSTRUMENTS,

- Microwave / Radio
- Structures & Antennas Distributed Aperture
- Particles: Charged & Neutral Fields & Waves

AEROASSIST & ATMOSPHERIC ENTRY

- Rigid Thermal Protection Systems Flexible Thermal Protection
- Rigid Hypersonic Decelerators Deployable Hypersonic Decelerators

DESCENT

- Attached Deployable Decelerators Trailing Deployable Decelerators Supersonic Retropropulsion
- Touchdown Systems Egress & Deployment Systems

Propulsion Systems Small Body Systems VEHICLE SYSTEMS TECHNOLOGY

- Separation Systems • System Integration and Analyses Atmosphere & surface characterization
- Modeling and Simulation Instrumentation and Health Monitoring

• GN&C Sensors and Systems

TA10·NANO-TECHNOLOGY

ENGINEERED MATERIALS & STRUCTURES

• Lightweight Structures Damage Tolerant Systems Coatings

Adhesives Thermal Protection & Control **ENERGY GENERATION & STORAGE**

 Energy Storage Energy Generation **PROPULSION**

Propellants Propulsion Components In-Space Propulsion SENSORS, ELECTRONICS &

DEVICES Sensors & Actuators Nanoelectronics









TA11 · MODELING, SIMULATION, MODELING, INFORMATION TECHNOLOGY & PROCESSING

COMPUTING

- Flight Computing
- Ground Computing MODELING

Software Modeling & Model-Checking Integrated Hardware & Software

Human-System Performance Modeling Science Modeling Frameworks, Languages, Tools &

SIMULATION

• Distributed Simulation Integrated System Lifecycle Simulation

Simulation-Based Systems Engineering Simulation-Based Training & Decision Support Systems

- INFORMATION PROCESSING Science, Engineering & Mission Data
- Lifecvcle Intelligent Data Understanding Semantic Technologies

Collaborative Science & Engineering

 Advanced Mission Systems TA12 MATERIALS, STRUCTURES, Fault Isolation and Diagnostics

MATERIALS.

• Lightweight Structure Computational Design

MECHANICAL SYSTEMS &

Flexible Material Systems Environment Special Materials

MANUFACTURING

STRUCTURES • Lightweight Concepts

Design & Certification Methods Reliability & Sustainment Test Tools & Methods Innovative, Multifunctional Concepts

MECHANICAL SYSTEMS Deployables, Docking and Interfaces Mechanism Life Extension Systems Electro-mechanical, Mechanical &

Micromechanisms Design & Analysis Tools and Methods Reliability / Life Assessment / Health Monitoring

Certification Methods MANUFACTURING

Manufacturing Processes Intelligent Integrated Manufacturing and Cyber Physical Systems Electronics & Optics Manufacturing Process

Sustainment Methods Loads and Environments

Sustainable Manufacturing

Nondestructive Evaluation

Model-Based Certification &

TA13 · GROUNI • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems Autonomous Command & Control for Ground and Integrated Vehicle / Ground

ENVIRONMENTAL AND GREEN

- **T**ECHNOLOGIES · Corrosion Prevention. Detection, & Mitigation
- Environmental Remediation & Site Restoration
- Preservation of Natural Eco Alternate Energy Prototypes
- AVAILABILITY • Advanced Launch Technologies Environment-Hardened

TECHNOLOGIES TO INCREASE

RELIABILITY AND MISSION

- Materials and Structures Inspection, Anomaly Detection & Îdentification
- Prognostics Technologies · Repair, Mitigation, and Recovery Technologies

Timing & Telemetry TECHNOLOGIES TO IMPROVE MISSION SAFETY/MISSION RISK • Range Tracking, Surveillance &

Flight Safety Technologies

 Landing & Recovery Systems & Components Weather Prediction and

Robotics / Telerobotics

Mitigation

Safety Systems TA14 ·THERMAL MANAGEMENT SYSTEMS

CRYOGENIC SYSTEMS • Passive Thermal Control

& Radiative)

Technologies

• Active Thermal Control

 Integration & Modeling THERMAL CONTROL SYSTEMS • Heat Acquisition Heat Transfer

• Heat Rejection & Energy Storage THERMAL PROTECTION SYSTEMS

Sensor Systems & Measurement

• Entry / Ascent TPS For any additional information: • Plume Shielding (Convective

JSC SUPPLEMENTAL DATA

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY IMPACT

ORBITAL DEBRIS

- Modeling
- Monitoring
- Mitigation

TO BE DETERMINED

 Remediation HYPERVELOCITY IMPACT

Material Composition

 Experimental Investigations TA17 EMERGING TECHNOLOGIES

The effort to develop the STRs began in 2010 when NASA identified fourteen technology areas and then assigned agency specialists to describe their technology area's top technical challenges, the spaceflight missions they could impact or enable, and - as a byproduct – the important terrestrial fields they could advance. The set of draft STRs, which cover both human and robotic technologies, was distributed publicly in December 2010. At the same time, NASA contracted with the National Research Council (NRC) to perform an independent critique of the draft roadmaps. Through the NRC's participation, public comment was received, and independent expert panels subsequently reviewed the comments, established evaluation criteria, identified gaps, and prioritized the technologies within each technology area. An overall steering committee of the NRC then furtheprioritized across the technology areas, and released their final report early in 2012.

NASA Space Technology Roadmaps

1/6

Space Technology Roadmaps (STRs) **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

HUMAN SPACE FLIGHT TECHNOLOGY NEEDS*

National Aeronautics and Space Administration



OFFICIAL NASA ROADMAPS













TA01·LAUNCH PROPULSION SYSTEMS

SOLID ROCKET PROPULSION

- Propellants
- Case Materials
- Nozzle Systems Hybrid Rocket Propulsion
- Fundamental Solid Propulsion Technologies

LIQUID ROCKET PROPUL-SION SYSTEMS

- CH₄/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants
- Fundamental Liquid Propulsion Technologies

Turbine Based Jet Engines

- PROPULSION SYSTEMS
- Advanced Fission TBCC Breakthrough Propulsion
 - **SUPPORTING TECHNOLOGIES**

 - (Flyback Boosters)

ENERGY STORAGE Air Collection &

- Propulsion Technologies ANCILLARY PROPULSION

 - Radioisotope
 - Fusion

- Regenerative Fuel Cells

Fundamental Ancillary Propulsion Technologies DISTRIBUTION

- Ground Launch Assist
- Air Launch / Drop Systems Space Tether Assist Beamed Energy / Energy
- Addition
- High Energy Density

SYSTEMS

SENSING & PERCEPTION

- 3-D Perception Relative Position & Velocity
- Estimation Terrain Mapping, Classification
- & Characterization Natural & Man-made
- Object Recognition Sensor Fusion for Sampling
- & Manipulation Onboard Science Data

MOBILITY

- Extreme Terrain Mobility
- Below-Surface Mobility Above-Surface Mobility
- Small Body/Microgra

MANIPUL ATION

- Robot Arms
- Modeling of Contact Dynamics
- Mobile Manipulation
- Robotic Drilling & Sample

Processing Human-Systems INTEGRATION

- Beamed Energy Propulsion • Multi-Modal Human-Systems Interaction

 - Robot-to-Suit Interfaces Intent Recognition &

 - Distributed Collaboration Common Human-Systems Interfaces
 - Safety, Trust, & Interfacing of Robotic Human Proximity Operations

Management & FDIR

Terrain Relative Navigation

vith Uncertainty

AUTONOMOUS RENDEZVOUS

Path & Motion Planning

• Relative Navigation Sensors

(long-, mid-, near-range)

iidance Algorithms

Docking & Capture

RTA Systems Engineering

Onboard Computing

Mission/System Managers

• Modularity/Commonality

for Autonomy/Automation

Verification & Validation o

omplex Adaptive Systems

Dynamic Planning &

Sequencing Tools

AUTONOMY

& Docking

Vehicle Systems

ontrol

TA03 · SPACE POWER &

Power Generation

- Energy Harvesting
- Autonomous Guidance & Multi-Agent CoordinationAdjustable Autonomy

- **ENERGY STORAGE**
- Flywheels

Power Management &

- Management & Control
- Wireless Power
- Transmission Conversion & Regulation
- CROSS CUTTING
- TECHNOLOGY
- Analytical Tools
- Green Energy Impact Multi-functional Structures • Alternative Fuels

ROBOTICS&AUTONOMOUS

OPTICAL COMM. & NAVIGATION

- Detector Development Large Apertures
- Acquisition & Tracking Atmospheric Mitigation
- RADIO FREQUENCY COMMUNICATIONS • Spectrum Efficient Technologies
- Power Efficient Technologies Propagation
- Flight & Ground Systems Earth Launch & Reentry Comm.
- Antennas INTERNETWORKING
- Disruptive Tolerant Networking Adaptive Network Topology Information Assurance
- Integrated Network Management Position, Navigation, and Timing
- Timekeeping & Time Distribution Onboard Auto Navigation &
- Sensors & Vision Processing Systems Auto Precision Formation Flying
- Auto Approach & Landing INTEGRATED TECHNOLOGIES
- Radio Systems Ultra Wideband
- Cognitive Networks Science from the Comm. System
- Hybrid Optical Comm. & RF/Optical Hybrid Technology
- REVOLUTIONARY CONCEPTS
- X-Ray Navigation X-Ray Communications
- Neutrino-Based Nav. & Tracking Quantum Key Distribution
- Quantum Communications SOIF Microwave Amplifier Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS &

- HABITATION SYSTEMS Air Revitalization
- Water Recovery & Managemen Waste Management

EXTRAVEHICULAR ACTIVITY SYSTEMS

- Pressure Garment Portable Life Support System
 Power, Avionics & Software
- **HUMAN HEALTH & PERFORMANCE**
- Medical Diagnosis / Prognosi ong-Duration Health ehavioral Health Human Factors

ENVIRONMENTAL MONITORING,

SAFETY & EMERGENCY RESPONSE Sensors: Air, Water, Microbial, etc. ire: Detection, Suppression, Recover Protective Clothing / Breathing

Remediation

- Risk Assessment Modeling ladiation Mitigation
- rotection Systems
- Radiation prediction

TA05 · COMMUNICATION & NAVIGATION







TA07 · HUMAN EXPLORATION **DESTINATION SYSTEMS**

- IN-SITU RESOURCE UTILIZATION
- Destination Reconnaissance. Prospecting, & Mapping
- Resource Acquisition
 Consumables Production
- Manufacturing Products & Infrastructure Emplacement SLISTAINABILITY &

SUPPORTABILITY

- Autonomous Logistics Management
- Maintenance Systems Repair Systems Food Production, Processing,

& Preservation "ADVANCED" HUMAN MOBILITY SYSTEMS

- EVA Mobility
- Off-Surface Mobility
- "ADVANCED" HABITAT SYSTEMS • Integrated Habitat Systems
- Smart" Habitate Artificial Gravity

MISSION OPERATIONS & SAFETY

- Crew Training Planetary Safety Integrated Flight Operations
- Integrated Risk Assessment Tools
- CROSS-CUTTING SYSTEMS Construction & Assembly
- Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, **OBSERVATORIES & SENSOR** SYSTEMS

REMOTE SENSING

INSTRUMENTS/SENSORS

- Detectors & Focal Planes Electronics
- Optical Components Microwave / Radio Lasers
- Cryogenic / Thermal **O**BSERVATORIES
- Mirror Systems Structures & Antennas
- Distributed Aperture In-SITU INSTRUMENTS/SENSOR
- Particles: Charged & Neutral Fields & Waves In-Situ

Rigid Thermal Protection System

igid Hypersonic Decelerators

Plexible Thermal Protection

eployable Hypersonic

AEROASSIST & ATMOSPHERIC ENTRY



Attached Deployable Decelerators Trailing Deployable Decelerators Supersonic Retropropulsion LANDING Touchdown Systems

- - VEHICLE SYSTEMS TECHNOLOGY Separation Systems ystem Integration and Analyses

Egress & Deployment System

- Atmosphere & surface characterization Modeling and Simulation
- Instrumentation and Health Monitoring GN&C Sensors and Systems

TA12 · MATERIALS, STRUCTURES, TA10·NANO-TECHNOLOGY MECHANICAL SYSTEMS &

STRUCTURES • Lightweight Structures Damage Tolerant Systems

ENGINEERED MATERIALS &

- Coatings
- Adhesives Thermal Protection & Control **ENERGY GENERATION & STORAGE**

Energy Storage Energy Generation

- **PROPULSION** Propellants
- Propulsion Components In-Space Propulsion
- SENSORS, ELECTRONICS &
- **D**EVICES Sensors & Actuators







TA11 · MODELING, SIMULATION, MODELING, INFORMATION TECHNOLOGY & PROCESSING

- COMPUTING

MODELING Software Modeling & Model-Checki

- Integrated Hardware & Software Human-System Performance Modeling
- Science Modeling Frameworks, Languages, Tools &

- SIMULATION
- Distributed Simulation Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering Simulation-Based Training &

Decision Support Systems

- INFORMATION PROCESSING Science, Engineering & Mission Data
- Lifecvcle Intelligent Data Understanding Semantic Technologies
- Collaborative Science & Engineering Advanced Mission Systems

MANUFACTURING MATERIALS

- Lightweight Structu
- Computational Design Flexible Material Systems Environment
- Special Materials **S**TRUCTURES
- Lightweight ConceptsDesign & Certification Methods Reliability & Sustainment Test Tools & Methods
- MECHANICAL SYSTEMS Deployables, Docking and Interfaces
- Electro-mechanical, Mechanical & Micromechanisms Design & Analysis Tools and Methods
- Reliability / Life Assessment / Health Monitoring Certification Methods

MANUFACTURING

- Intelligent Integrated Manufacturing and Cyber Physical Systems Electronics & Optics Manufacturing Process Sustainable Manufacturing
- Nondestructive Evaluation Model-Based Certification & Sustainment Methods Loads and Environments

CROSS-CUTTING

TA13 · GROUNI • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE

- Storage, Distribution &
- Automated Alignment,
- Coupling, & Assembly Systems Autonomous Command & Control for Ground and Integrated Vehicle / Ground

ENVIRONMENTAL AND GREEN

- **T**ECHNOLOGIES Corrosion Prevention
- Detection, & Mitigatio Environmental Remediation & Site Restoration

Alternate Energy Prototypes TECHNOLOGIES TO INCREASE

RELIABILITY AND MISSION

- AVAILABILITY • Advanced Launch Technologies Environment-Hardened
- Materials and Structures Inspection, Anomaly Detection & Îdentification Fault Isolation and Diagnostic
- ognostics Technologies Repair, Mitigation, and Recovery Technologies

Timing & Telemetry TECHNOLOGIES TO IMPROVE

- MISSION SAFETY/MISSION RISK • Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components Weather Prediction and

Mitigation

• Robotics / Telerobotics Safety Systems TA14 · THERMAL MANAGEMENT

SYSTEMS

• Heat Acquisition

Heat Transfer

- **CRYOGENIC SYSTEMS** Passive Thermal Control
- Active Thermal Contro Integration & Modeling THERMAL CONTROL SYSTEMS
- Heat Rejection & Energy THERMAL PROTECTION SYSTEMS

• Entry / Ascent TPS

 Plume Shielding (Convective) & Radiative) Sensor Systems & Measurement Technologies

TA16 ORBITAL THE OPERATIONAL LIFE-CYCLE AND HYPERVELOCITY

ORBITAL DEBRIS

- Modeling Monitoring
- Mitigation
- Remediation
- HYPERVELOCITY IMPACT Material Composition

JSC SUPPLEMENTAL DATA TA15 · RESERVED



TO BE DETERMINED

As the National Aeronautics and Space Administration (NASA) prepares to extend human presence throughout the solar system, technical capabilities must be developed to enable long duration flights to destinations such as near Earth asteroids, Mars, and extended stays on the Moon. As part of the NÁSA Human Spaceflight Architecture Team, a Technology Development Assessment Team has identified a suite of critical technologies needed to support this broad range of missions. Dialog between mission planners, vehicle developers, and technologists was used to identify a minimum but sufficient set of technologies, noting that needs are created by specific mission architecture requirements, yet specific designs are enabled by technologies. Further consideration was given to the re-use of underlying technologies to cover multiple missions to effectively use scarce resources. This suite of critical technologies is expected to provide the needed base capability to enable a variety of

nology needs associated with the STR Technology Area Breakdown Structure. HAT- TABS Crosswalk

design reference mission context for the human space flight technology needs see: Critical Technology Determination for Future Human Space Flight

possible destinations and missions. For the list of human spaceflight tech-For additional details, background, and

Space Technology Roadmaps (STRs) **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

TA02 IN-SPACE PROPULSION TECHNOLOGIES

• Liquid Storable

Hybrid

Liquid Cryogenic

Cold Gas/Warm Gas

NON-CHEMICAL PROPULSION

• Micro-propulsion

• Electric Propulsion

Tether Propulsion

ADVANCED (TRL <3)

Fusion Propulsion

PROPULSION TECHNOLOGIES

Electric Sail Propulsion

High Energy Density

• Antimatter Propulsion

Solar Sail Propulsion

CHEMICAL PROPULSION

- Systems
- LH₂/LOX Base
- AIR BREATHING
- RBCC Detonation Wave Engines (Open Cycle)
- Ramjet/Scramjet Engines (Accelerators) Deeply-cooled Air Cycles
- Enrichment System Fundamental Air Breathing

Systems

Main Propulsion Systems (Excluding Engines) Launch Abort Systems Thrust Vector Control Systems

Health Management &

Pyro & Separation Systems

Auxiliary Control Systems

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

JSC CORE TECHNOLOGY COMPETENCIES

National Aeronautics and Space Administration



OFFICIAL NASA ROADMAPS













CHEMICAL PROPULSION

Liquid Cryogenic

Micro-propulsion

• Electric Propulsion

Solar Sail Propulsion

• Thermal Propulsion

Tether Propulsion

Fusion Propulsion

High Energy Density

• Antimatter Propulsion

SUPPORTING TECHNOLOGIES

ENERGY STORAGE

Power Generation

Radioisotope

Analytical Tools

• Alternative Fuels

Green Energy Impact

Multi-functional Structures

Fusion

• Energy Harvesting

Breakthrough Propulsion

TA03 · SPACE POWER &

Advanced Fission

NON-CHEMICAL PROPULSION

• Liquid Storable

Hybrid

TAO1 LAUNCH PROPULSION TA02 IN-SPACE PROPULSION SYSTEMS TECHNOLOGIES

SOLID ROCKET PROPULSION SYSTEMS

- Propellants
- Case Materials Nozzle Systems
- Hybrid Rocket Propulsion
- Fundamental Solid Propulsion Technologies

LIQUID ROCKET PROPUL-SION SYSTEMS

- LH₂/LOX Based RP/LOX Based
- Detonation Wave Engines
- (Closed Cycle) Propellants
- Fundamental Liquid Propulsion Techn

AIR BREATHING PROPULSION SYSTEMS

- TBCC RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters) Ramjet/Scramjet Engines
- (Accelerators)
- Deeply-cooled Air Cycles Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

ANCILLARY PROPULSION Systems

- Auxiliary Control System Main Propulsion Systems (Excluding Engines)
- Fission Launch Abort Systems Thrust Vector Control
- **ENERGY STORAGE** Health Management & Flywheels
- Regenerative Fuel Cells Pyro & Separation System Fundamental Ancillary Power Management & DISTRIBUTION

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist
- Wireless Power Air Launch / Drop Systems Transmission Space Tether Assist Conversion & Regulation
- Beamed Energy / Energy Addition CROSS CUTTING TECHNOLOGY
- High Energy Density

TA04 · ROBOTICS, ROBOTICS&AUTONOMOUS SYSTEMS

SENSING & PERCEPTION

- Terrain Mapping,
- Classification & Characterization Natural & Man-made Object Recognition
- Sensor Fusion for Sampling Onboard Science Data Analysis

MOBILITY

- Extreme Terrain Mobility Below-Surface Mobility
 - Above-Surface Mobil Small Body/Microgravity

MANIPUL ATION

- Cold Gas/Warm Gas
 - Robot Arms Dexterous Manipulators Modeling of Contact Dynamics
 - Mobile Manipulation Robotic Drilling & Sample

Processing HUMAN-SYSTEMS

- ADVANCED (TRL <3) PROPULSION TECHNOLOGIES INTEGRATION • Beamed Energy Propulsion
- Multi-Modal Human Electric Sail Propulsion stems Interaction
 - pervisory Contro
 - .obot-to-Śuit Interface Intent Recognition &
 - Distributed Collaboration ommon Human-Systems
 - Safety, Trust, & Interfacing of Robotic Human Proximity perations

AUTONOMY • Vehicle Systems

Management & FDIR

- Dynamic Planning & Sequencing Tools
- ontrol Multi-Agent CoordinationAdjustable Autonomy
- Terrain Relative Navigation Path & Motion Planning vith Uncertainty

AUTONOMOUS RENDEZVOUS & Docking

- Relative Navigation Sensor ong-, mid-, near-range)
- uidance Algorithms Docking & Capture Mission/System Managers

RTA Systems Engineering

Verification & Validation of Complex Adaptive Systems

Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

- Detector Development Large Apertures
- Acquisition & Tracking · Atmospheric Mitigation

RADIO FREQUENCY COMMUNICATIONS

 Spectrum Efficient Technologie Power Efficient Technologies ropagation

INTERNETWORKING

 Disruptive Tolerant Networking Adaptive Network Topology Information Assurance • Integrated Network Managemen

Earth Launch & Reentry Comm.

- Position, Navigation, and Timing
- Timekeeping & Time Distribution Onboard Auto Navigation &
- Maneuver • Sensors & Vision Processing Systems
- Auto Precision Formation Flying
- INTEGRATED TECHNOLOGIES
- Radio Systems
- Jltra Wideband Cognitive Networks
- Science from the Comm. System Hybrid Optical Comm. &
- RF/Optical Hybrid Technology
- REVOLUTIONARY CONCEPTS
- X-Ray Navigation X-Ray Communications
- Neutrino-Based Nav. & Tracking Quantum Key Distribution Quantum Communications
- SOIF Microwave Amplifier • Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, HABITATION SYSTEMS

ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS &

- HARITATION SYSTEMS Air Revitalization
- Water Recovery & Management Waste Management

EXTRAVEHICULAR ACTIVITY SYSTEMS Pressure Garment

- Portable Life Support SystemPower, Avionics & Software HUMAN HEALTH & PERFORMANCE
- Medical Diagnosis / Prognosis Long-Duration Health ehavioral Health

Human Factors ENVIRONMENTAL MONITORING SAFETY & EMERGENCY RESPONSE

• Sensors: Air, Water, Microbial, etc. Fire: Detection, Suppression, Recovery Protective Clothing / Breathing

RADIATION

- Risk Assessment Modeling Radiation Mitigation
- Protection Systems · Radiation prediction





TA07 · HUMAN EXPLORATION **DESTINATION SYSTEMS**

IN-SITU RESOURCE UTILIZATION

- Destination Reconnaissance Prospecting, & Mapping
- Resource Acquisition
- Manufacturing Products

& Infrastructure Emplacement SUSTAINABILITY &

• Autonomous Logistics Management

SUPPORTABILITY

- Maintenance Systems
- Repair Systems Food Production, Processing, & Preservation

"ADVANCED" HUMAN MOBILITY SYSTEMS

- Off-Surface Mobility "ADVANCED" HABITAT SYSTEMS
- Integrated Habitat Systems Habitat Evolution Smart" Habitats

Artificial Gravity MISSION OPERATIONS & SAFETY

- Crew Training Planetary Safety Integrated Flight Operations
- Integrated Risk Assessment Tools

CROSS-CUTTING SYSTEMS Construction & Assembly Particulate Contamination

Prevention & Mitigation TA08 · SCIENCE INSTRUMENTS,

OBSERVATORIES & SENSOR SYSTEMS

REMOTE SENSING INSTRUMENTS/SENSORS

- Detectors & Focal Planes Electronics • Optical Components
- Microwave / Radio Lasers Cryogenic / Thermal
- **O**BSERVATORIES Mirror Systems Structures & Antennas
- Distributed Aperture In-SITU INSTRUMENTS/SENSOR • Particles: Charged & Neutral
- Fields & Waves

TA09 · ENTRY, DESCENT & ANDING SYSTEMS

AFROASSIST & ATMOSPHERIC ENTRY

- Flexible Thermal Protection
- Systems Rigid Hypersonic Decelerators Deployable Hypersonic Decelerators

DESCENT

LANDING

- Attached Deployable Decelerators Trailing Deployable Decelerators • Supersonic Retropropulsion
- Touchdown Systems Egress & Deployment :
- Propulsion Systems Small Body Systems

VEHICLE SYSTEMS TECHNOLOGY • Separation Systems

- System Integration and Analyses Atmosphere & surface characterization
- Modeling and Simulatio nstrumentation and Health Monitoring

GN&C Sensors and Systems

TA10·NANO-TECHNOLOGY

ENGINEERED MATERIALS & STRUCTURES

- Lightweight Structures Damage Tolerant Systems
- Coatings Adhesives

Energy Storage

 Thermal Protection & Control **ENERGY GENERATION & STORAGE**

Energy Generation **PROPULSION**

- Propulsion Components
- In-Space Propulsion SENSORS, ELECTRONICS &
- **D**EVICES Sensors & Actuators Nanoelectronics







TA11 · MODELING, SIMULATION, MODELING. INFORMATION TECHNOLOGY & PROCESSING

COMPUTING

 Flight Comput Ground Computir

MODELING

- Software Modeling & Model-Checking Integrated Hardware & Software
- Science Modeling

Frameworks, Languages, Tools &

SIMULATION Distributed Simulation

Integrated System Lifecycle Simulatio Simulation-Based Systems Engineering Simulation-Based Training &

INFORMATION PROCESSING

Advanced Mission Systems

- Science, Engineering & Mission Data
- Intelligent Data Understanding Collaborative Science & Engineering

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

MATERIALS

- Lightweight Structu Computational Design
- Flexible Material Systen

Special Materials **S**TRUCTURES

• Lightweight Concepts Design & Certification Methods Reliability & Sustainment

Test Tools & Methods Innovative, Multifunctional Concer MECHANICAL SYSTEMS

- Deployables, Docking and Interface Mechanism Life Extension Systems Electro-mechanical, Mechanical &
- Micromechanisms Design & Analysis Tools and Metho Reliability / Life Assessment / Health Monitoring

Certification Methods MANUFACTURING

Intelligent Integrated Manufacturing and Cyber Physical Systems Electronics & Optics Manufacturing

Process

CROSS-CUTTING

Nondestructive Evaluation Model-Based Certification &

TA13 · GROUN • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution & Conservation of Fluids
- Automated Alignment, Coupling, & Assembly Systems
- Autonomous Command & Control for Ground and Integrated Vehicle / Ground

ENVIRONMENTAL AND GREEN **T**ECHNOLOGIES

- · Corrosion Prevention. Detection, & Mitigation
- Environmental Remediation & Site Restoration Preservation of Natural Eco

systems Alternate Energy Prototypes TECHNOLOGIES TO INCREASE RELIABILITY AND MISSION

AVAILABILITY

- Advanced Launch Technologies Environment-Hardened Materials and Structures
- Inspection, Anomaly Detection & Îdentification Fault Isolation and Diagnostics
- · Repair, Mitigation, and Recovery Technologies Communications, Networking,

Timing & Telemetry TECHNOLOGIES TO IMPROVE

Prognostics Technologies

- MISSION SAFETY/MISSION RISK • Range Tracking, Surveillance & Flight Safety Technologies
- Landing & Recovery Systems & Components Weather Prediction and Mitigation Robotics / Telerobotics

Safety Systems TA14 ·THERMAL MANAGEMENT

SYSTEMS

CRYOGENIC SYSTEMS • Passive Thermal Control • Active Thermal Control

Integration & Modeling

THERMAL CONTROL SYSTEMS • Heat Acquisition

• Heat Rejection & Energy THERMAL PROTECTION SYSTEMS

& Radiative)

- Entry / Ascent TPS Plume Shielding (Convective)
- Sensor Systems & Measurement

JSC SUPPLEMENTAL DATA

TA16 ORBITAL DEBRIS AND HYPERVELOCITY

ORBITAL DEBRIS

- Modeling Monitorin
- Mitigation

To Be Determined

HYPERVELOCITY IMPACT

 Material Comp Experimental Investigations



All NASA centers, based upon each center's unique qualifications, conduct research and technology developments to assure the longterm viability of America's space program. Each center's domain of technical excellence is based upon unique skills, personnel, and facilities that are aligned with the technology needs for NASA's aeronautics and science and human spaceflight missions. JSC's core

technology competencies are directly tied to human exploration and include power generation, robotic manipulation and mobility systems, autonomous rendezvous and docking, radio frequency communications, position, navigation and timing technologies, environmental control and life support and habitation systems, human health and performance, radiation protection technologies, entry, descent and landing systems, modeling, simulation and information processing technologies, lightweight structures, mechanical systems, non-destructive evaluation, thermal control and thermal protection, and orbital debris and hypervelocity impact systems. The JSC Chief Technologist as well as the Center's technology management and development organizations assure that the Center's advanced technology planning, development, and infusion activities are strategically aligned with future NASA missions and programs.

For any additional information, visit us at R&D Partnership Database (accessible to JSC employees only) or contact us by email at jsc-technology@mail.nasa.gov

Space Technology Roadmaps (STRs) **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

REVISED—12/20/12

PARTNERSHIP POTENTIAL – JSC PERSPECTIVE

National Aeronautics and Space Administration













TAO1 LAUNCH PROPULSION TA02 IN-SPACE PROPULSION SYSTEMS **TECHNOLOGIES**

SOLID ROCKET PROPULSION

- Propellants Case Materials
- Nozzle Systems
- Hybrid Rocket Propulsion Systems
- Fundamental Solid Propulsion Technologies LIQUID ROCKET PROPUL-

SION SYSTEMS LH_a/LOX Based

- RP/LOX Based CH4/LOX Based
- Detonation Wave Engines
- (Closed Cycle) Propellants
- Fundamental Liquid Propulsion Technologies AIR BREATHING

PROPULSION SYSTEMS

- TBCC RBCC
- Detonation Wave Engines (Open Cycle) Turbine Based Jet Engines
- (Flyback Boosters) Ramjet/Scramjet Engines
- (Accelerators) Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

ANCILLARY PROPULSION Systems

- Auxiliary Control Systems Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems Thrust Vector Control
- Systems Health Management &
- Pyro & Separation Systems Fundamental Ancillary

Propulsion Technologies UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist Air Launch / Drop Systems
- Space Tether Assist Beamed Energy / Energy
- Addition
- High Energy Density

TA04 · ROBOTICS, SYSTEMS

- Relative Position & Velocity
- Estimation Terrain Mapping, Classification
- Natural & Man-made Object Recognition
- Sensor Fusion for Sampling & Manipulation

- CHEMICAL PROPULSION • Liquid Storable
 - Liquid Cryogenic
- Hybrid Cold Gas/Warm Gas • Micro-propulsion

NON-CHEMICAL PROPULSION

- Electric Propuls Solar Sail Propulsion
- Thermal Propulsion • Tether Propulsion

ADVANCED (TRL <3) PROPULSION TECHNOLOGIES

- Beamed Energy Propulsion Electric Sail Propulsion
- Fusion Propulsion High Energy Density
- Antimatter Propulsion Advanced Fission
- Breakthrough Propulsion
- Supporting Technologies Propellant Storage &
- TA03 · SPACE POWER & **ENERGY STORAGE**

Power Generation

- Energy Harvesting
- Radioisotope Fission
- Fusion

ENERGY STORAGE

- Flywheels
- Regenerative Fuel Cells Power Management &

DISTRIBUTION

- FDIR
- Management & Control
- Wireless Power Transmission
- Conversion & Regula CROSS CUTTING

TECHNOLOGY

- Analytical Tools
- Green Energy Impact
- Multi-functional Structures • Alternative Fuels

ROBOTICS&AUTONOMOUS

SENSING & PERCEPTION

- 3-D Perception
- & Characterization
- Onboard Science Data Analysis

MOBILITY

- Below-Surface Mobility Above-Surface Mobility Small Body/Microgravity
 - Mobility MANIPUL ATION

Robot Arms

- Modeling of Contact Dynamics
- Mobile Manipulation Robotic Drilling & Sample

Processing HUMAN-SYSTEMS

- INTEGRATION Multi-Modal Human
- Systems Interaction
- Robot-to-Suit Interfaces Intent Recogn
- Distributed Collaboration Common Human-Systems
- Safety, Trust, & Interfacing of Robotic/ Human Proximity Operations

AUTONOMY

- Vehicle Systems Management & FDIR
- Dynamic Planning & Sequencing Tools Autonomous Guidance & Control
- Multi-Agent Coordination Adjustable Autonomy
- errain Relative Navigation Path & Motion Plann

AUTONOMOUS RENDEZVOUS & DOCKING

- Relative Navigation Sensors (long-, mid-, near-range) Docking & Capture
- Mission/System Managers for Autonomy/Automa-

RTA Systems Engineering Modularity/Commonality

- Verification & Validation of Complex Adaptive
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

- Large Apertures
- Atmospheric Mitigation
- RADIO FREQUENCY COMMUNICATIONS
- Propagation Flight & Ground Systems

INTERNETWORKING

- Extreme Terrain Mobility Information Assurance
 - Position, Navigation, and Timing Timekeeping & Time Distribution
 - Onboard Auto Navigation &
 - Auto Precision Formation Flying
 - INTEGRATED TECHNOLOGIES · Radio Systems
 - Cognitive Networks Science from the Comm. System
 - Hybrid Optical Comm. &
 - REVOLUTIONARY CONCEPTS X-Ray Navigation
 - X-Ray Communications Neutrino-Based Nav. & Tracking Quantum Key Distribution
 - Quantum Communications SOIF Microwave Amplifier

Using Nanosat Constellations

ENVIRONMENTAL CONTROL

HARITATION SYSTEMS Air Revitalization Water Recovery & Managemen

Habitation

- Pressure Garment
- Power, Avionics & Software HUMAN HEALTH & PERFORMANCE
 - ehavioral Health

ENVIRONMENTAL MONITORING SAFETY & EMERGENCY RESPONSE

- Sensors: Air, Water, Microbial, etc. Fire: Detection, Suppression, Recovery
- RADIATION • Risk Assessment Modeling
- Radiation prediction

Remediation

- Detector Development
- Acquisition & Tracking

- Spectrum Efficient Technologies Power Efficient Technologies
- Earth Launch & Reentry Comm. Antennas
- Disruptive Tolerant Networking Adaptive Network Topology
- Integrated Network Management
- Sensors & Vision Processing Systems
- Auto Approach & Landing
- Ultra Wideband
- RF/Optical Hybrid Technology
- Reconfigurable Large Apertures

TA06 · HUMAN HEALTH, HABITATION SYSTEMS

& LIFE SUPPORT SYSTEMS &

EXTRAVEHICULAR ACTIVITY SYSTEMS

- Medical Diagnosis / PrognosiLong-Duration Health

Human Factors

- Protective Clothing / Breathing
- Radiation Mitigation

Optical Components Microwave / Radio

OBSERVATORIES

In-SITU INSTRUMENTS/SENSOR • Particles: Charged & Neutral

TA09 · ENTRY, DESCENT &

AEROASSIST &



TA07 · HUMAN EXPLORATION **DESTINATION SYSTEMS**

IN-SITU RESOURCE UTILIZATION

- Destination Reconnaissance Prospecting, & Mapping Resource Acquisition
 Consumables Production
- Manufacturing Products & Infrastructure Emplacemen SLISTAINABILITY &
- SUPPORTABILITY • Autonomous Logistics Management
- Maintenance System Repair Systems Food Production, Processing, & Preservation
- "ADVANCED" HUMAN MOBILITY SYSTEMS EVA Mobility

Surface Mobility

 Off-Surface Mobility "ADVANCED" HABITAT SYSTEMS • Integrated Habitat Systems

Smart" Habitate Artificial Gravity

- MISSION OPERATIONS & SAFETY Planetary Safety Integrated Flight Operations
- Integrated Risk Assessment Tools CROSS-CUTTING SYSTEMS

Construction & Assembly

Particulate Contamination

Prevention & Mitigation TA08 · SCIENCE INSTRUMENTS, **OBSERVATORIES & SENSOR** SYSTEMS

REMOTE SENSING INSTRUMENTS/SENSORS

- Detectors & Focal Planes Electronics
- Cryogenic / Thermal
- Mirror Systems Structures & Antennas • Distributed Aperture

Fields & Waves

In-Situ

ATMOSPHERIC ENTRY Rigid Thermal Protection

lexible Thermal Protection Rigid Hypersonic Decelerators Deployable Hypersonic

Decelerators DESCENT

- Attached Deployable Decelerators
 Trailing Deployable Decelerators
- LANDING • Touchdown Systems

characterization

Egress & Deployment Systems

- VEHICLE SYSTEMS TECHNOLOGY System Integration and Analyses Atmosphere & surface
- Modeling and Simu • Instrumentation and Health GN&C Sensors and System

TA10·NANO-ENGINEERED MATERIALS & STRUCTURES

 Lightweight Structures Damage Tolerant Systems Coatings Adhesives

Thermal Protection & Control **ENERGY GENERATION & STORAGE**

PROPULSION • Propellants Propulsion Components

Energy Storage

Energy Generation

 In-Space Propulsion SENSORS, ELECTRONICS & **D**EVICES

Sensors & Actuators







MODELING, TA11 · MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

COMPUTING

- Flight Computing
- Ground Computing MODELING
 - Integrated Hardware & Software
 - Human-System Performance Modeling Science Modeling

Frameworks, Languages, Tools &

- SIMULATION
- Distributed Simulation Integrated System Lifecycle Simula
- Simulation-Based Systems Engineer Simulation-Based Training &

Decision Support Systems

- INFORMATION PROCESSING Science, Engineering & Mission Data
- Intelligent Data Understanding TA12 · MATERIALS, STRUCTURES, **MECHANICAL SYSTEMS &**

MATERIALS.

MANUFACTURING

Lightweight Structu

- Computational Design Flexible Material Systems Environment Special Materials
- **S**TRUCTURES Reliability & Sustainment

Test Tools & Methods Innovative, Multifunctional Concer

MECHANICAL SYSTEMS Deployables, Docking and Interfaces Electro-mechanical, Mechanical &

Intelligent Integrated Manufacturing

Electronics & Optics Manufacturing

Design & Analysis Tools and Methods Reliability / Life Assessment / Health Monitoring

Micromechanisms

Certification Methods MANUFACTURING

Process CROSS-CUTTING

and Cyber Physical Systems

Model-Based Certification & Sustainment Methods

Loads and Environments

TA13 · GROUN • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution &
- Automated Alignment, Coupling, & Assembly Systems Autonomous Command & Control for Ground and

Integrated Vehicle / Ground

ENVIRONMENTAL AND GREEN

- **TECHNOLOGIES** Corrosion Prevention Detection, & Mitigation
- Environmental Remedia tion &

Site Restoration

RELIABILITY AND MISSION

Preservation of Natural Alternate Energy Prototypes TECHNOLOGIES TO INCREASE

- AVAILABILITY • Advanced Launch Technologies Environment-Hardened
- Materials and Structures Inspection, Anomaly Detection & Identification Fault Isolation and Diag
- Prognostics Technologies · Repair, Mitigation, and Recovery Technologies Communications, Networking,

Timing & Telemetry

TECHNOLOGIES TO IMPROVE MISSION SAFETY/MISSION RISK • Range Tracking, Surveillance &

Flight Safety Technologies

Landing & Recovery Systems

& Components Weather Prediction and Mitigation Robotics / Telerobotics TA14 ·THERMAL MANAGEMENT

SYSTEMS CRYOGENIC SYSTEMS

• Passive Thermal Control

• Active Thermal Control

Integration & Modeling

THERMAL CONTROL SYSTEMS • Heat Acquisition • Heat Rejection & Energy

THERMAL PROTECTION SYSTEMS

Entry / Ascent TPS

 Plume Shielding (Convective) & Radiative) Sensor Systems & Measurement Technologies

TA16 ORBITA AND HYPERVELOCITY

- Modeling
- Monitoring
- Mitigation Remediation

TO BE DETERMINED

HYPERVELOCITY IMPACT Material Composition Experimental Investigations

JSC SUPPLEMENTAL DATA

TA17 EMERGING TECHNOLOGIES

Our experience in space exploration benefits life on earth. NASA has many capabilities and assets that may be applicable to your industry. Whether you are working in commercial space, aerospace or non-aerospace industries, we want to pursue collaborative partnerships in R & D, advanced technology and new technology applications. We invite you to explore Johnson Space Center's world-class expertise and capabilities, including an established infrastructure, unique engineering facilities, integrated project management, safety and risk analysis, human habitability, health and performance expertise, and proven design, development, testing and operation of complex systems designed for extreme environments. We are committed to helping you leverage our expertise and capabilities to meet your

Contact the JSC Strategic Opportunities and Partnership Development Office by phone 281-483-3000 or jsc-partnerships@ mail.nasa.gov by email to begin a conversation about your interests. For information visit: JSC Human Spaceflight Capabilities

Space Technology Roadmaps (STRs) **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

REVISED—12/20/12

COMMERCIALIZATION POTENTIAL – JSC PERSPECTIVE

OFFICIAL NASA ROADMAPS













CHEMICAL PROPULSION

Liquid Cryogenic

Cold Gas/Warm Gas

NON-CHEMICAL PROPULSION

• Micro-propulsion

• Electric Propulsion

Thermal PropulsionTether Propulsion

ADVANCED (TRL <3)

Propulsion Technologies

Electric Sail Propulsion

High Energy Density

Breakthrough Propulsion

Fusion Propulsion

• Antimatter Propulsion

SUPPORTING TECHNOLOGIES

Advanced Fission

• Beamed Energy Propulsion

Solar Sail Propulsion

• Liquid Storable

Hybrid

SOLID ROCKET PROPULSION

- Propellants
- Case Materials
- Nozzle Systems Hybrid Rocket Propulsion
- Systems Fundamental Solid Propulsion Technologies

LIQUID ROCKET PROPUL-SION SYSTEMS

- LH_a/LOX Based
- RP/LOX Based
- CH4/LOX Based Detonation Wave Engines
- (Closed Cycle) Propellants
- Fundamental Liquid Propulsion Technologies AIR BREATHING

PROPULSION SYSTEMS

- TBCC RBCC
- Detonation Wave Engines
- (Open Cycle) Turbine Based Jet Engines
- (Flyback Boosters) Ramjet/Scramjet Engines (Accelerators)
- Deeply-cooled Air Cycles Air Collection &
- Enrichment System Fundamental Air Breathing

Propulsion Technologies ANCILLARY PROPULSION

Systems Auxiliary Control Systems

- Main Propulsion Systems (Excluding Engines)
- Launch Abort Systems Thrust Vector Control
- Health Management &
- Pyro & Separation Systems Fundamental Ancillary Propulsion Technologies

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist
- Air Launch / Drop Systems Space Tether Assist
- Beamed Energy / Energy Nuclear

TA04 · ROBOTICS, ROBOTICS&AUTONOMOUS SYSTEMS

SENSING & PERCEPTION

Relative Position & Velocity

Estimation Terrain Mapping, Classification

& Characterization Natural & Man-made Object Recognition Sensor Fusion for Sampling

Onboard Science Data Analysis

- Extreme Terrain Mobility Below-Surface Mobility Above-Surface Mobility
- Small Body/Microgravity Mobility

MANIPUL ATION Robot Arms

- Modeling of Contact Dynamics
- lobile Manipulation ollaborative Manipulation Robotic Drilling & Sample

HUMAN-SYSTEMS INTEGRATION

- Multi-Modal Human-Systems Interaction
- Robot-to-Suit Interfaces Intent Recognition &
- Distributed Collaboration ommon Human-Systems
- Safety, Trust, & Interfacing of Robotic Human Proximity

Management & FDIR

TA03 · SPACE POWER & AUTONOMY Vehicle Systems **ENERGY STORAGE**

Power Generation

Radioisotope

ENERGY STORAGE

Flywheel

Regenerative Fuel Cells

• Management & Control

Conversion & Regulation

Multi-functional Structures

Power Management &

Wireless Power

CROSS CUTTING

• Analytical Tools

• Alternative Fuels

• Green Energy Impact

TECHNOLOGY

Fission

Fusion

Batteries

DISTRIBUTION

FDIR

- Dynamic Planning & Sequencing Tools **Energy Harvesting** Autonomous Guidance & Chemical (Fuel Cells, Heat
 - ontrol Multi-Agent Coordination Adjustable Autonomy
 - Terrain Relative Navigation Path & Motion Planning ith Uncertainty

AUTONOMOUS RENDEZVOUS & Docking

- Relative Navigation Sensor ong-, mid-, near-range) Guidance Algorithms
- Docking & Capture Mission/System Managers
- for Autonomy/Automation

RTA Systems Engineering

- Modularity/Commonality Verification & Validation of Complex Adaptive Systems
- Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

- Detector Development Large Apertures
- Acquisition & Tracking

 Atmospheric Mitigation RADIO FREQUENCY COMMUNICATIONS

- Spectrum Efficient Technologie ower Efficient Technologies Propagation Flight & Ground Systems
- Earth Launch & Reentry Comm.

INTERNETWORKING

 Adaptive Network Topology • Integrated Network Management

Position, Navigation, and Timing • Timekeeping & Time Distribution

- Onboard Auto Navigation & Maneuver • Sensors & Vision Processing Systems Relative & Proximity Navigation
- Auto Precision Formation Flying Auto Approach & Landing INTEGRATED TECHNOLOGIES

Radio Systems Jltra Wideband

- Cognitive Networks Science from the Comm. System • Hybrid Optical Comm. &
- Navigation Sensors
- REVOLUTIONARY CONCEPTS
- X-Ray Navigation X-Ray Communications
- Neutrino-Based Nav. & Tracking Quantum Key Distribution
- Quantum Communications SOIF Microwave Amplifier
- Reconfigurable Large Apertures Using Nanosat Constellations

TA06 · HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEMS & HARITATION SYSTEMS

Air Revitalization

Water Recovery & Managemen Habitation

EXTRAVEHICULAR ACTIVITY SYSTEMS Pressure Garment

 Portable Life Support System Power, Avionics & Software HUMAN HEALTH & PERFORMANCE

 Medical Diagnosis / Prognosi Long-Duration Health Behavioral Health

ENVIRONMENTAL MONITORING. SAFETY & EMERGENCY RESPONSE

• Sensors: Air, Water, Microbial, etc. Fire: Detection, Suppression, Recovery Protective Clothing / Breathing Remediation

RADIATION

- Radiation Mitigation
- Protection Systems Radiation prediction
- Note: Evaluation is based upon competitive, commercial market potential over next decade and thus

TA09 · ENTRY, DESCENT &

TA07 · HUMAN EXPLORATION

DESTINATION SYSTEMS

IN-SITU RESOURCE UTILIZATION

Resource Acquisition

• Autonomous Logistics

Food Production, Processing

"ADVANCED" HUMAN MOBILITY

Management

Repair Systems

& Preservation

Surface Mobility

Habitat Evolution

· "Smart" Habitats

Artificial Gravity

Crew Training

Systems

SYSTEMS

REMOTE SENSING

Electronics

OBSERVATORIES

INSTRUMENTS/SENSORS

• Detectors & Focal Planes

Optical Components

Cryogenic / Thermal

Structures & Antennas

Distributed Aperture

In-SITU INSTRUMENTS/SENSOR

Mirror Systems

Fields & Waves

In-Situ

Microwave / Radio

Planetary Safety

CROSS-CUTTING SYSTEMS

Construction & Assembly

Particulate Contamination

Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS,

OBSERVATORIES & SENSOR

Off-Surface Mobility

"ADVANCED" HABITAT SYSTEMS

• Integrated Habitat Systems

MISSION OPERATIONS & SAFETY

Integrated Flight Operations

Integrated Risk Assessment Tools

EVA Mobility

Maintenance Systems

SUSTAINABILITY &

SUPPORTABILITY

SYSTEMS

Destination Reconnaissance

Prospecting, & Mapping

Consumables Production

Manufacturing Products

& Infrastructure Emplacement

AEROASSIST &

ATMOSPHERIC ENTRY Rigid Thermal Protection Systems

Rigid Hypersonic Decelerators Deployable Hypersonic Decelerators

DESCENT

LANDING

- Attached Deployable Decelerators Trailing Deployable Decelerators • Supersonic Retropropulsion
- Touchdown Systems Egress & Deployment Systems
- Propulsion Systems Small Body Systems

VEHICLE SYSTEMS TECHNOLOGY

- Separation Systems • System Integration and Analyses Atmosphere & surface characterization
- Modeling and Simulation • Instrumentation and Health
- Monitoring • GN&C Sensors and Systems

TA10·NANO-TECHNOLOGY

ENGINEERED MATERIALS & STRUCTURES

- Lightweight Structures Damage Tolerant System
- Coatings
- Thermal Protection & Control **ENERGY GENERATION & STORAGE**

Energy Storage Energy Generation

PROPULSION

- Propellants Propulsion Components In-Space Propulsion
- SENSORS, ELECTRONICS & **D**EVICES
- Sensors & Actuators
- Nanoelectronics Miniature Instruments







TA11 · MODELING, SIMULATION, MODELING, INFORMATION TECHNOLOGY & PROCESSING

- **C**OMPUTING • Flight Computing
- Ground Computing MODELING
- Integrated Hardware & Software
- Human-System Performance Modeling Science Modeling Frameworks, Languages, Tools &

Software Modeling & Model-Checki

SIMULATION

- Distributed Simulation Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering Simulation-Based Training & Decision Support System

INFORMATION PROCESSING

- Science, Engineering & Mission Data Lifecvcle
- Intelligent Data Understanding
- Collaborative Science & Engineering Advanced Mission Systems

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

MATERIALS.

- Computational Design
- Environment

STRUCTURES

- Design & Certification Methods
- Reliability & Sustainment Test Tools & Methods Innovative, Multifunctional Concepts

MECHANICAL SYSTEMS Deployables, Docking and Interface Mechanism Life Extension Systems

- Design & Analysis Tools and Methods Reliability / Life Assessment / Health Monitoring
- Certification Methods MANUFACTURING

Manufacturing Processes

- Intelligent Integrated Manufacturing and Cyber Physical Systems Electronics & Optics Manufacturing rocess Sustainable Manufacturing

CROSS-CUTTING

Model-Based Certification & Sustainment Methods

TA13 · GROUN • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE THE OPERATIONAL LIFE-CYCLE

- Storage, Distribution &
- Conservation of Fluids Automated Alignment,
- Coupling, & Assembly Systems Autonomous Command & Control for Ground and Integrated Vehicle / Ground

ENVIRONMENTAL AND GREEN **T**ECHNOLOGIES

- Corrosion Prevention Detection, & Mitigation
- Environmental Remediation & ite Restoration Preservation of Natural Eco-
- Alternate Energy Prototypes **TECHNOLOGIES TO INCREASE**

RELIABILITY AND MISSION

AVAILABILITY

- Advanced Launch Technologies Environment-Hardened
- Materials and Structures Inspection, Anomaly Detection & Îdentification
- Fault Isolation and Diagnostics rognostics Technolo • Repair, Mitigation, and
- Recovery Technologies Timing & Telemetry
- MISSION SAFETY/MISSION RISK • Range Tracking, Surveillance &
- Flight Safety Technologies Landing & Recovery Systems & Components Weather Prediction and

TECHNOLOGIES TO IMPROVE

Mitigation Robotics / Telerobotics Safety Systems

TA14 ·THERMAL MANAGEMENT SYSTEMS

CRYOGENIC SYSTEMS

- Passive Thermal Contro Active Thermal Contro
- THERMAL CONTROL SYSTEMS • Heat Acquisition Heat Transfer

Integration & Modeling

Heat Rejection & Energy THERMAL PROTECTION SYSTEMS

- Entry / Ascent TPS Plume Shielding (Convective)
- & Radiative) Sensor Systems & Measurement Technologies

JSC SUPPLEMENTAL DATA

National Aeronautics and Space Administration

TA15 · RESERVED

TA16 · ORBITAL DEBRIS AND HYPERVELOCITY IMPACT

ORBITAL DEBRIS

- Modeling
- Mitigation

• Remediation HYPERVELOCITY IMPACT

 Material Composition • Experimental Investigations



To Be Determined

The Technology Transfer and Commercialization Office at NA-SA's Johnson Space Center (JSC) facilitates the transfer and commercialization of NASA-sponsored research and technology as well as the use of JSC's unique research and development capabilities and facilities. The office works with entrepreneurs, companies, and investors, helping them license NASAdeveloped technologies so they can bring them to the marketplace. We actively market technologies that show a high degree of potential, creating appropriate promotional collateral, seeking out prospective licensees, and negotiating win-win deals. NASA patent licenses may be exclusive, co-exclusive, partially exclusive, or non-exclusive.

For more information contact us by calling 281-483-3809, sending email to jsc-techtran@mail.nasa.gov or visiting us on the web at: JSC Technology Transfer

Space Technology Roadmaps (STRs) • Particles: Charged & Neutral **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

OFFICIAL NASA ROADMAPS











TECHNOLOGIES

• Liquid Storable

Hybrid

Liquid Cryogenic

Cold Gas/Warm Gas

NON-CHEMICAL PROPULSION

• Micro-propulsion

• Electric Propulsion

Solar Sail Propulsion

• Thermal Propulsion

Tether Propulsion

ADVANCED (TRL <3)

PROPULSION TECHNOLOGIES

Fusion Propulsion

• Antimatter Propulsion

SUPPORTING TECHNOLOGIES

Propellant Storage &

Advanced Fission

High Energy Density

Breakthrough Propulsion

TA02 IN-SPACE PROPULSION



SOLID ROCKET PROPULSION

- Propellants
- Case Materials
- Nozzle Systems Hybrid Rocket Propulsion
- Systems Fundamental Solid Propulsion Technologies

LIQUID ROCKET PROPUL-SION SYSTEMS

- LH_a/LOX Based RP/LOX Based
- CH4/LOX Based
- Detonation Wave Engines (Closed Cycle)
- Propellants Fundamental Liquid
- Propulsion Technologies AIR BREATHING

PROPULSION SYSTEMS

- TBCC
- RBCC
- Detonation Wave Engines (Open Cycle)
- Turbine Based Jet Engines (Flyback Boosters) Ramjet/Scramjet Engines
- (Accelerators)
- Deeply-cooled Air Cycles
- Air Collection & Enrichment System
- Fundamental Air Breathing Propulsion Technologies

ANCILLARY PROPULSION Systems

- Auxiliary Control Systems Main Propulsion Systems (Excluding Engines)
 - Launch Abort Systems
- Thrust Vector Control Systems
- Health Management & Pyro & Separation Systems
- Fundamental Ancillary Propulsion Technologies

UNCONVENTIONAL / OTHER PROPULSION SYSTEMS

- Ground Launch Assist
- Air Launch / Drop Systems
- Space Tether Assist Beamed Energy / Energy
- Addition
- High Energy Density

REVISED—12/20/12

ROBOTICS&AUTONOMOUS SYSTEMS

SENSING & PERCEPTION

- 3-D Perception Relative Position & Velocity
- Estimation Terrain Mapping, Classification
- & Characterization Natural & Man-made
- Object Recognition Sensor Fusion for Sampling & Manipulation
- Onboard Science Data Analysis

MOBILITY

- CHEMICAL PROPULSION
 - Below-Surface Mobility Above-Surface Mobility
 - Small Body/

- Modeling of Contact Dynamics

- Beamed Energy Propulsion Electric Sail Propulsion
 - Robot-to-Suit Interfaces

 - Interfaces Safety, Trust, &
 - Human Proximity Operations

TA03 · SPACE POWER & **ENERGY STORAGE**

Power Generation

- Energy Harvesting

- Radioisotope Fission
- Fusion

ENERGY STORAGE

- Flywheels
- Regenerative Fuel Cells

Power Management &

- DISTRIBUTION FDIR
- Management & Control Distribution & Transmission RTA Systems Engineering Wireless Power
- Transmission Conversion & Regulation
- CROSS CUTTING
- TECHNOLOGY • Analytical Tools

• Alternative Fuels

• Green Energy Impact Multi-functional Structures

- Large Apertures

- Power Efficient Technologies
- Flight & Ground Systems
- Antennas

- Extreme Terrain Mobility

MANIPUL ATION

- Robot Arms
- Mobile Manipulation
- Robotic Drilling & Sample

Processing HUMAN-SYSTEMS

- INTEGRATION • Multi-Modal Human-Systems Interaction
- Supervisory Control
- Intent Recognition &
- Distributed Collaboration Common Human-Systems
- Interfacing of Robotic/

AUTONOMY

- Vehicle Systems
- Management & FDIR • Dynamic Planning & Sequencing Tools
- Autonomous Guidance & Control
- Multi-Agent Coordination
- Adjustable Autonomy Terrain Relative Navigation

• Path & Motion Planning with Uncertainty **A**UTONOMOUS RENDEZVOUS

- & Docking • Relative Navigation Sensors (long-, mid-, near-range)
- iidance Algorithms Docking & Capture
- Mission/System Managers for Autonomy/Automation

Modularity/Commonality Verification & Validation of

Complex Adaptive Systems Onboard Computing

TA05 · COMMUNICATION & NAVIGATION

OPTICAL COMM. & NAVIGATION

- Detector Development
- Acquisition & Tracking · Atmospheric Mitigation

RADIO FREQUENCY COMMUNICATIONS

- Spectrum Efficient Technologies Propagation
- Earth Launch & Reentry Comm.

INTERNETWORKING

- Disruptive Tolerant Networking Adaptive Network Topology
- Information Assurance • Integrated Network Management Position, Navigation, and Timing
- Timekeeping & Time Distribution Onboard Auto Navigation &
- Maneuver Sensors & Vision Processing Systems
- Relative & Proximity Navigation Auto Precision Formation Flying Auto Approach & Landing
- INTEGRATED TECHNOLOGIES · Radio Systems
- Ultra Wideband
- Cognitive Networks Science from the Comm. System Hybrid Optical Comm. &
- RF/Optical Hybrid Technology
- REVOLUTIONARY CONCEPTS X-Ray Navigation
- X-Ray Communications Neutrino-Based Nav. & Tracking Quantum Key Distribution
- Quantum Communications SOIF Microwave Amplifier • Reconfigurable Large Apertures

Using Nanosat Constellations TA06 · HUMAN HEALTH,

HABITATION SYSTEMS

ENVIRONMENTAL CONTROL

& LIFE SUPPORT SYSTEMS & HARITATION SYSTEMS

- Air Revitalization
- Vater Recovery & Managemen Waste Management

• Habitation EXTRAVEHICULAR ACTIVITY SYSTEMS

- Pressure Garment Portable Life Support System Power, Avionics & Software
- HUMAN HEALTH & PERFORMANCE Medical Diagnosis / Prognosis Long-Duration Health

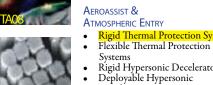
Behavioral Health Human Factors ENVIRONMENTAL MONITORING.

SAFETY & EMERGENCY RESPONSE • Sensors: Air, Water, Microbial, etc. • Fire: Detection, Suppression, Recovery Protective Clothing / Breathing

Remediation

- Risk Assessment Modeling Radiation Mitigation
- Protection Systems Radiation prediction





TA07 · HUMAN EXPLORATION **DESTINATION SYSTEMS**

- IN-SITU RESOURCE UTILIZATION
- Destination Reconnaissance
- Resource Acquisition Consumables Production

SUSTAINABILITY &

- Management
- Maintenance Systems Repair Systems

"ADVANCED" HUMAN MOBILITY

- EVA Mobility
- Off-Surface Mobility
- "ADVANCED" HABITAT SYSTEMS • Integrated Habitat Systems

"Smart" Habitats Artificial Gravity

- MISSION OPERATIONS & SAFETY Crew Training
- Planetary Safety

Integrated Risk Assessment Tools **CROSS-CUTTING SYSTEMS**

REMOTE SENSING

OBSERVATORIES

INSTRUMENTS/SENSORS • Detectors & Focal Planes Electronics

- Optical Components
- Mirror Systems Structures & Antennas

• Particles: Charged & Neutral Fields & Waves

TA09 · ENTRY, DESCENT &

Rigid Hypersonic Decelerators

Attached Deployable Decelerators

Trailing Deployable Decelerators

Egress & Deployment Systems

• System Integration and Analyses

Deployable Hypersonic

Supersonic Retropropulsion

• Touchdown Systems

Propulsion Systems

VEHICLE SYSTEMS TECHNOLOGY

Modeling and Simulation

• Instrumentation and Health

GN&C Sensors and System

TA10·NANO-TECHNOLOGY

Small Body Systems

• Separation Systems

Atmosphere & surface

ENGINEERED MATERIALS &

• Lightweight Structures

Damage Tolerant Systems

Thermal Protection & Control

ENERGY GENERATION & STORAGE

STRUCTURES

Coatings

Adhesives

PROPULSION

DEVICES

Propellants

Energy Storage

Energy Generation

SENSORS, ELECTRONICS &

Sensors & Actuators

Miniature Instruments

Nanoelectronics

characterization

Monitoring

Systems

DESCENT

LANDING

Decelerators





- Prospecting, & Mapping
- Manufacturing Products & Infrastructure Emplacement
- SUPPORTABILITY • Autonomous Logistics

Food Production, Processing, & Preservation

- SYSTEMS

Habitat Evolution

- In-Space Propulsion

Construction & Assembly Particulate Contamination Prevention & Mitigation

TA08 · SCIENCE INSTRUMENTS, **OBSERVATORIES & SENSOR** SYSTEMS

- Microwave / Radio Cryogenic / Thermal
- Distributed Aperture In-SITU INSTRUMENTS/SENSOR



- COMPUTING • Flight Computing
- Ground Computing MODELING

Software Modeling & Model-Checking Integrated Hardware & Software

Human-System Performance Modeling Science Modeling

Frameworks, Languages, Tools & Standards

- SIMULATION
- Distributed Simulation Integrated System Lifecycle Simulation
- Simulation-Based Systems Engineering Simulation-Based Training &

Decision Support Systems INFORMATION PROCESSING

- Science, Engineering & Mission Data Lifecvcle
- Intelligent Data Understanding Semantic Technologies Collaborative Science & Engineering

TA12 · MATERIALS, STRUCTURES, MECHANICAL SYSTEMS &

Advanced Mission Systems

MANUFACTURING

MATERIALS. • Lightweight Structure Computational Design

Flexible Material Systems Environment Special Materials

STRUCTURES • Lightweight Concepts Design & Certification Methods

Reliability & Sustainment Test Tools & Methods Propulsion Components Innovative, Multifunctional Concepts MECHANICAL SYSTEMS

Deployables, Docking and Interfaces Mechanism Life Extension Systems Electro-mechanical, Mechanical & Micromechanisms Design & Analysis Tools and Methods

Reliability / Life Assessment / Health

Monitoring Certification Methods MANUFACTURING

Intelligent Integrated Manufacturing and Cyber Physical Systems Electronics & Optics Manufacturing Process

Sustainment Methods Loads and Environments

CROSS-CUTTING

Sustainable Manufacturing

Nondestructive Evaluation

Model-Based Certification &

TA13 GROUNI • GROUND & SYSTEMS PROCESSING

TECHNOLOGIES TO OPTIMIZE

- THE OPERATIONAL LIFE-CYCLE • Storage, Distribution &
- Conservation of Fluids Automated Alignment, Coupling, & Assembly Systems Autonomous Command &

Control for Ground and Integrated Vehicle / Ground ENVIRONMENTAL AND GREEN

- **T**ECHNOLOGIES · Corrosion Prevention.
- Detection, & Mitigation Environmental Remediation &
- Site Restoration Preservation of Natural Eco systems Alternate Energy Prototypes

RELIABILITY AND MISSION AVAILABILITY • Advanced Launch Technologies

TECHNOLOGIES TO INCREASE

& Îdentification

Timing & Telemetry

Flight Safety Technologies

TECHNOLOGIES TO IMPROVE

& Components

Mitigation Robotics / Telerobotics

Weather Prediction and

 Environment-Hardened Materials and Structures Inspection, Anomaly Detection

Fault Isolation and Diagnostics

- Prognostics Technologies · Repair, Mitigation, and priorities as follows: Recovery Technologies
- ISC Technology Competencies (pg. 3) MISSION SAFETY/MISSION RISK
 - Each technical area in the Space Technology Roadmap Technology Area Breakdown Structure (TABS) was assigned a raw score (high priority = 0.9, medium priority = 0.3, low priority = 0.1) which was multiplied by the weights for each of the four priority areas. Overlap scores were computed by summing the four weighted scores for each TABS area.

HSF Technology Needs JSC Core Technology Competencies 0.3 Partnership Potential 0.3 Commercialization Potential 0.0

The Overlap score for the Monitoring Technology area was calculated to be: $0.9 \times 0.4 + 0.3 \times 0.4 + 0.4 + 0.3 \times 0.4 + 0.4 + 0.4 + 0.3 \times 0.4 + 0.4 + 0.4 + 0.3$ $0.4 + 0.3 \times 0.1 + 0.0 \times 0.0 = 0.51$. A specified number of TABS areas with the highest Overlap scores were selected to create this Areas of Significant Overlap chart.

Partnership Potential (pg. 4) • Range Tracking, Surveillance & Commercialization Potential (pg. 5) Landing & Recovery Systems

Safety Systems TA14 · THERMAL MANAGEMEN SYSTEMS

CRYOGENIC SYSTEMS • Passive Thermal Control • Active Thermal Control

Heat Transfer Heat Rejection & Energy THERMAL PROTECTION SYSTEMS

Integration & Modeling

THERMAL CONTROL SYSTEMS

• Heat Acquisition

Entry / Ascent TPS

Plume Shielding (Convective) & Radiative) Sensor Systems & Measurement Technologies

TA16 ORBITA AND HYPERVELOCITY

JSC SUPPLEMENTAL DATA

Modeling Monitoring

Mitigation

To be Determined

 Remediation HYPERVELOCITY IMPACT Material Composition

• Experimental Investigations

TA17 EMERGING TECHNOLOGIES

These "Areas of Significant Overlap" highlight

identified in these "prioritization charts". The

JSC Technology Working Group (JTWG)

the overlaps between weighted priorities

determined the weighting factors that should be associated with each of the four sets of Human Space Flight (HSF) Needs (pg. 2) 0.4

For example, the TA06 Human Health, Life Support & Habitation Systems / Radiation / Monitoring Technology area was assigned the following raw scores:

Space Technology Roadmaps (STRs) **TECHNOLOGYAREABREAKDOWNSTRUCTURE**

* Highlighted areas represent highly-rated intersections between TABS and Needs, Competencies/Project Focus, and Commercial/